Accordingly, recommendations were passed to the Maritime Commander that in order to effectively handle the salvage aspects, it would be necessary to request adequate, competent, logistical assistance as expeditiously as possible from wherever available. It was also separately recommended to Department of Transport officials in Port Hawkesbury that if the stern section could be kept afloat, it should be towed to its original destination on T. Point. Tigger for the removal of remaining cargo, however the stern section sank shortly thereafter, and was reported to be lodged in a precarious position on the bottom in danger of toppling into deeper water.

**SURVEY PHASE**

Consultations between Maritime Command, representatives of Standard/Imperial Oil, and the Department of Transport resulted in the Fleet Diving Unit (Atlantic) being directed by Maritime Command, to undertake a hull survey of the wreck, and to conduct diving operations as requisite to attach the necessary fittings to the tanks to enable removal of the remaining cargo.

The Department of Transport (Coast Guard) were arranging to lay mooring buoys at the wreck.

An advance survey diving team proceeded by road to Port Hawkesbury on 23 February, and subsequently boarded the CCGS SIR WILLIAM ALEXANDER on 24 February. Concurrently, trials were carried out in conjunction with Imperial Oil personnel to determine a means of attaching valves and hoses to the wreck and pump out the cargo. From the trials, a method was evolved to attach valves to the deck of the tanker with explosive bolts, and drilling a hole through the deck with a “hot tap” drill.

This method is the subject of a separate report, and is attached as Annex A.

During the period from 25 to 27 February, a diving survey was made of both the forward section of the wreck, still hard aground on Cerberus Rock, and of the after section to be surveyed, the diving team operating from CCGS SIR WILLIAM ALEXANDER which also laid the first mooring buoys in the area. The CCGS RALLY was used to conduct the diving survey of the forward section. Both surveys were carried out with a certain amount of difficulty owing to adverse wind and sea conditions, and air temperatures generally less than 20°F, which caused some icing of diving equipment.

Diving on the wreck was also made more difficult by the heavy, adhesive black cargo oil. This was the first experience with what was to become a constant problem throughout the whole salvage task.

The survey established the following information. The after section is lying on an even keel in ninety feet of water on a gravel bottom in position latitude 45° 28’ 16’’ N, longitude 61° 06’ 27’’ W on an approximate heading of 230° (T). Funnel awash at high water. See Fig. 1 and 2. The visible part of the hull from the bilge keel up, appeared intact from number six tank, aft. A small rupture was detected on the starboard side at the turn of the bilge into number eight tank. The extent of rupturing below the turn of the bilge could not be determined. The ship had broken across number five tank which was consequently completely open to the sea. Subsequent examination established that number six port, and number six centre tanks were also open. At the time of the initial survey, it appeared that there was some oil leaking from the open part of number five. This later proved to be coming from within number six. There were some broken lines on the upper deck. Minor amounts of oil were running in streams from these, and from the ends of the oil lines at number five. It appeared that the majority of the oil cargo in tanks six, seven, eight, and nine was more or less intact, with whatever remained in the ship’s own fuel tanks. It was later determined that tanks nine port and nine starboard were empty due to unsuccessful attempts by the salvage company to pump air into these tanks, which resulted in a loss of their cargo. Fig. 3 shows a hull plan sketch of the tanks which retained the majority of their cargo. This was later estimated to be approximately 1,500,000 gallons. Two portable low pressure air compressors were secured on deck, forward of the pump room sky light. Another compressor was lying on the bottom 50 feet from the starboard side of the hulk. Above number five starboard tank, a king-post remained intact. The corresponding post on the port side was missing.

During the examination of the fractured number five tank, it was determined that the deck thickness was 1/8 of an inch for the wing tanks, and 3/8 of an inch for the centre tanks.

The forward section was found to be lying with the starboard side hard against Cerberus Rock pinnacle. The radar mast of the bridge structure is in a position 090° (T), in 100 feet from the rock at 45° 27’ 55’’ N, 60° 06’ 22’’ W. See Fig. 1. The ball is in an average depth of 50 feet, with the upper part of the bridge structure awash. The general line of the hulk is 220° (T), and it has an estimated 20’ list to starboard. The foc’le and bridge structure were found to be more or less intact. The hull all along the starboard side was crushed and open nearly to the main deck, from forward of the bridge structure nearly to the foc’le break. The main deck was fractured longitudinally on both sides of the cut-walk from number three tank to number one. The fracture on the port side had a maximum opening of about 2 inches. The one on the starboard side started as a hairline at tank number three and widened to a vertical displacement of approximately eight feet. There was some movement between the broken edges, and water surge caused scouing of some "gobs" of oil from within the ruptured tanks. The forecast was down, and lying diagonally across the deck and over the side. Aft the bridge structure, the hull was completely broken up and open, through the much abraded rock beneath. The examination of the forward section resulted in the conclusion that although all tanks were ruptured, at least at the bottom, there was a probability that some oil remained trapped at the tops of tanks one, two and three port, and possibly three centre.

The details of the foregoing surveys were reported to the staff at Operation Oil headquarters in the evening of 27 February.

**OIL RECOVERY PHASE**

Diving tender YMT 12 departed from the Fleet Diving Unit at Dartmouth early on 27 February, and made a rough and uncomfortable passage to Canso Straits against headwinds and seas, with considerable icing of the superstructure; finally arriving at Port Hastings and securing alongside CCGS NARWAL at 1600 Saturday, 28 February.

Due to several minor defects incurred on passage, YMT 12 remained alongside for repairs until the afternoon of Sunday, 1 March, when passage was made to Achutan in preparation for an early start diving on the wreck next day.

On March 2, after first clearing away several stray mooring lines fouling the hulk, YMT 12 was moored in position over the stern section. A “nozzle”, gate valve and “hot tap” drill was secured to number eight centre tank using the “Coat Gun” to attach the bolts for the nozzle and the first drilling commenced. A 45 gallon oil barrel was rigged to the “hot tap” drill to provide a flotation lift for ease of handling underwater. This was just one example of many instances throughout the whole operation where flotation was utilized by the divers to handle heavy gear. It was often used in preference to lowering from above due to the presence of a ground swell on the surface.

While diving was in progress, several broken oil lines were pluged to curtail oil leakage, which, though not in quantity, made diving activities much more difficult by fouling the water, and consequently diving suits and equipment. Drilling continued until the early afternoon without achieving penetration of the 3/4 inch plate, when a rising wind and sea necessitated unmooring and returning to Achutan. The problem was initially suspected, and subsequently proven, to be due to the drill being located over a longitudinal difficulty in avoiding these strength members was largely caused by non-availability of ship’s plans. Although it was known through advice from Standard Oil consultants that the ship was of “Islewood” construction, with frames spaced at 12 ft. in centres,
and longitudinal beams at 30 inch centres. When plans were later obtained, they were of the class only, and did not show many modifications which had apparently been incorporated in this particular vessel. Consequently, and ironically, when the plans were available, they tended to be misleading, and the most reliable method of avoiding the longitudinals was found to be by tapping the deck with a hammer.

During the 3rd and 4th of March, adverse weather prevented diving on the wreck. However these days were put to good advantage by the diving officers in meeting with and briefing the personnel of the salvage tug CURB owned by Murphy Pacific Salvage Company, which had now arrived in Port Hastings. The services of this vessel, an ex USN salvage tug (ARS) had been obtained to provide, together with a suitable container barge, the capability for pumping the tanker C oil from the wreck. Owing to limited sea-keeping capabilities of CURB, it had been anticipated that CURB’s arrival on the scene would considerably enhance the capability for all weather diving in the Cabotus Rock area, which was in an open roadstead completely exposed to the vagaries of winter weather conditions. It was also assumed that CURB would be equipped with the diving capability she had had as a USN vessel, and would therefore relieve the cramped conditions in the 90 foot long YMT 12.

It was somewhat of a revelation to find that CURB had a total crew (civilian) of 29; had only the very minimum of diving equipment, and only two divers. She also had no medical facilities, which necessitated a medical assistant being added to the complement of YMT 12.

The requirements for mooring CURB, and subsequently the barge which will receive the oil, were discussed. These briefings and discussions resulted in the conclusions that CURB was not suitable as a diving platform for this operation, and YMT 12 was required to continue in this function, using CURB or the oil barge as a lee. The remaining king post on the wreck was an obstruction to CURB’s being able to moor, and the diving team removed this by use of explosives at first opportunity.

In conjunction with the familiarization of CURB personnel, the master and mate were embarked in YMT 12 and taken to the wreck location.

Also during 4 March, a diving team carried out a survey of the foundations of Lennox passage bridges.

On March 5, diving operations were resumed on the wreck, continuing drilling on number eight centre tank, which was finally penetrated in the afternoon. This resulted in considerable elation, being the first success in the drilling, and proved the feasibility of the procedure. Operations were hampered by ice on the deck of the tender, water temperature of 28°F, considerable fouling of divers and equipment by oil, and a rising sea and wind which reached 45 knots before operations were terminated. This day also saw CURB in the area commencing to lay a four point moor.

During the period 5-11 March, drilling operations followed a general routine which usually consisted of checking the weather conditions at 0400, and if suitable, YMT 12 departing Archait to as to arrive on the wreck at first light. On some days, weather curtailed or prevented diving.

The tender would take up a three point moor over the wreck and continue drilling operations. As previously described, during these early stages the drilling operations were somewhat time-consuming owing to the frequent occurrence of striking longitudinals. Trouble was also experienced through frequent freezing of the air vanes and hoses of the pneumatic drill. Additional delay was caused on the 7th March when the clutch shaft of the drill parted and had to be taken to Port Hawkesbury for repairs.

On 6 March, CURB completed laying the four point moor and obtained the assistance of YMT 12 to stretch the mooring legs.

On 9 March, an additional “hot tap” drill was received. This one was driven hydraulically, and had been provided by the Department of Transport. Before it could be made to operate satisfactorily in the cold water, several modifications were progressively carried out, both experimentally, and in consultation with the manufacturer’s representatives. These details are described in Annex A.

By the 11th March, tanks eight centre and eight port had been penetrated and fitted for hose attachment. At first, each tank was fitted with two nozzles and valves, intending only for steam entry and the other for pumping oil out. However, subsequently it was found that one valve per tank was sufficient, the steam being pumped down into the tank by use of a 2 inch line within the oil hose, and also through a nipple in the side of the nozzle.

On the evening of 11 March, YMT 12 dragged the four in number, four ton, close-in moorings clear of the ARROW stern section at the request of CURB so that they would not be in the way of mooring the oil barge IRVING WHALE, which was arriving on scene 12 March.

The barge was in position over the wreck by the morning of 13 March. YMT 12 secured alongside and commenced working in conjunction with the barge crew (who were from CURB) to attach the first hose to tank eight centre. On this first hose attachment, many problems were encountered and solved. The operation consequently took most of the day. The lessons learned were put to good use with subsequent hoses.

The following general procedure was evolved.

A 90 degree elbow was attached to the gate valve to allow the bight of the hose to lie on the deck of the tanker and provide scope for the rise and fall of the barge in the swell, and tide range. A jackstay was attached between the barge and the barge; the end of the hose was secured to the jackstay with a strap and shackle, and thereby lowered down the jackstay to the elbow. In some cases, where it was necessary to clear the sag of the hose over the cat-walk or other obstructions, it was supported in more than one place to the jackstay. A flotation barrel was used on occasion to aid in manhandling the hose.

On 14th March, considerable swell made conditions unsuitable for diving. However, the end of the hose was inadvertently lost from the barge, so YMT 12 proceeded alongside the WHALE with some difficulty and carried out diving to recover the lost end; under very marginal conditions.

Diving operations were resumed on 15 March, and continued during daylight hours until the afternoon of the 16th, when deteriorating weather forced a halt in activities, and necessitated the IRVING WHALE being removed from the moor and taken to Mulgrave for shelter. On 15th, the clutch shaft of the pneumatic drill broke once again, which caused some delay.

During this period, the feasibility of attaching the nozzles to the side of the tank tops and drilling horizontally into them as illustrated in Annex A was investigated. This idea was subsequently discarded for the following reasons:

- The tank tops were constructed of only quarter inch plate, and might easily rupture and cause an oil spill; COX GUN ammunition of the correct load for plate thickness was not available; and, nozzles with curved flanges could not be manufactured locally with sufficient accuracy.

During the night of 16 March, and until the afternoon of the 17th, a strong southwesternly gale made the berths at Archait jetty completely untenable for YMT 12. It became necessary to anchor in the lee of Jerseymen Island. The inadequacy of the diving tender’s anchor and cable made necessary constant vigilance throughout the night.

On 18 March, the diving tender moved one of the four ton moorings at the wreck to the anchorage in the lee of Jerseymen Island to provide more adequate holding in future gales.

Diving operations were resumed on 19 March and continued daily until 21 March, the following tanks were penetrated and were fitted with valves and elbows ready for hose attachments; eight starboard, nine centre; seven centre, and seven starboard.
Orders were received to remove the funnel of the ARROW to ensure that it would not be in the way of the IRVING WHALE when she returned to position. This was undertaken with regret, as it served as a very good point of reference for the week's position, and would make an excellent cofferdam should any attempt at refloating the hulk be considered in the future. This removal commenced 19 March, using a series of explosive cutting charges, and was completed on 20 March. As each of many sections was severed, it was towed clear with the diving tender. The necessity to keep the charges as small as possible to minimize the risk of damage to the tanks made the removal a time-consuming process. The result gave a clearance of approximately 12 ft. over the superstructure, and left a hole with a mean diameter of 20 ft. Some structural damage to the deck immediately abuts the funnel location, and to the engine room skylights, also resulted.

On the evening of 21 March, the barge's moorings were cleared of stray lines and made ready for her return, anticipated 25 March. Additional pumping capabilities were being installed while in Mulgrave.

CURR returned with IRVING WHALE on the morning of the 23rd and secured in the mooring. Diving was resumed to recover the hose to eight centre tank and to rig additional hoses. Deteriorating weather allowed only the hose to eight centre to be hooked up that day. Unfortunately, this hose was once again lost overnight and required recovery in the morning.

During the 24th and 25th of March, hoses were attached to the following tanks and pumping commenced: nine centre, eight port and eight starboard.

Considerable difficulty was experienced trying to locate suitable positions on the ship's bunkers' tanks for the drill, owing to the clutter of piping in this area, and the overhang of the deck above.

On the afternoon of 25 March, after fitting a nozzle and valve in what seemed the only available location on the centre bunker tank, it was found that the drill would not quite fit through the tank and the tank was placed out of a small wedge in the deck-head. This most regrettable jarred open the tank-top of the centre bunker, and the bunker fuel within escaped in an oil spill. Large quantities of peat moss were dispersed over the escaping oil, which at this time did not appear to be in great quantity.

Radio difficulties prevented an immediate report of the spill. YMT 12 recovered gear and proceeded to Arichat where a report was passed by telephone.

At 1830 on 25th, the diving tender was ordered to proceed to sea with Captain Madsen of Imperial Oil and Captain Stuart of the Department of Transport aboard to act as OTC for the oil spill contingency plan forces ashore. Underway by 1930, YMT 12 remained at this tank overnight, determining and reporting the location and quantity of the oil spill. By 0600 on 26 March, it was evident that the oil was well dispersed and moving offshore. All marine units were accordingly secured.

Due to the requirement to rest personnel and repair equipment, diving for 26 March was cancelled.

Adverse weather prevented resuming operations until 28 March. From 28 March to 2 April, the following was accomplished: Tanks seven port and bunker starboard were penetrated and fitted for hose connections. Tanks eight centre and eight port were pumped clear of oil. The hose from eight port was shifted to seven port. Problems were being encountered in getting oil from eight starboard, so the hose was moved to seven starboard. It was determined that eight starboard required another penetration. This was achieved 2 April. The wing bunker tanks were found to be empty. During the afternoon of 2nd April, with a gale forecast, IRVING WHALE slipped 19 hoses with the assistance of divers and was removed from the mooring and taken to Mulgrave by CURR.

In the evening of 2 April, YMT 12 departed Arichat and proceeded to Port Hastings, just ahead of a rising gale, to obtain technical assistance in repairing several mechanical and electrical defects from HMCS CAPE SCOTT which had now joined the task force as a logistics support and accommodation vessel. On arrival, no sheltered berth could be obtained, and the tender was forced to secure alongside the exposed wall at the entrance to the lock, ahead of CAPE SCOTT. Heavy seas caused superficial damage to the port rubbing strake, and the tender experienced a very uncomfortable night. CAPE SCOTT technicians boarded on arrival and worked throughout the night on YMT 12 defects—CAPE SCOTT also assisted in rigging extra berthing lines to ease pressure of diving tender on dockside.

After completing repairs and loading stores, YMT 12 returned to Arichat in the evening of 4 April.

Weather conditions prevented the WHALE from returning to the wreck until 1330 on 6 April. Diving was then commenced to recover hoses. By the end of the day, hoses to the following tanks had been brought aboard WHALE and pumping resumed: seven port, seven centre, seven starboard, eight port and eight centre.

On 7 April, tank nine centre was pumped out and the hose removed and attached to eight starboard. Tank six starboard was penetrated and fitted for pumping; the last one to be drilled.

On this day also a detailed re-survey of the forward section of the tanker was carried out to definitely establish the presence or absence of oil cargo remaining. This examination disclosed that the two or three heavy gales since the initial brief survey two months previously had caused considerable disintegration of the hull; with the result that it was firmly established that no oil in quantity remained. At the time of the first survey, the port side of the hull was more or less intact, which made it possible that some oil might be trapped in the upper parts of one, two and three port tanks. The hull was now extensively wracked and ripped open. At the same time, settling had taken place onto the rock beneath. All tanks were open to the sea. It was possible to enter through the many rents in the hull side and see right through the hull to the opposite side of the ship. There was a vestige of oil remaining trapped in those tank tops which were still in situ.

Between 9 April and 11 April, diving and pumping operations were able to continue without any major interruptions. Tanks were progressively pumped free of oil, and hoses were shifted accordingly. As each tank was emptied, the elbow and gate valve were removed and a blanking plug fitted in lieu. By the evening of 10 April, all tanks were empty and blanked off except six, seven and eight starboard.

By the afternoon of 11 April, tanks six and seven starboard were empty and capped. Water was being pumped from eight starboard and it was considered to be empty. However, the hose was found to be leaking at the joints on removal. In fact, the joints separated during recovery, and the tank appeared to have some oil remaining. This was reported to the salvage master aboard the barge. Information was received that the tank was not considered to contain any large quantity of oil and instructions were given to cap it off. This completed the pumping operations. YMT 12 proceeded to Arichat, and the barge IRVING WHALE was unmoored and towed to Mulgrave by CURR.

The diving team remained at Arichat during 12th and 13th of April, generally cleaning the diving tender and equipment. On the afternoon of Sunday, 12th, a diving display was staged for the benefit of the people of Arichat. When the crew of the two army helicopters who were operating in the area learned of the plans, they supplemented the demonstration with a flying display, which resulted in a well-balanced combined operation. This was publicized on the previous evening in the local branch of the Canadian Legion, and on the next morning by announcements in the churches of the area. The result was an overwhelming turn-out of the populace, which created a considerable traffic jam, and a dense crowd on the jetty. The public were permitted aboard the tender in controlled numbers. A special feature for the children was provided in an opportunity to "fish for pop", with divers attaching the "catches".
On 14 April, at 1700 the diving team from Fleet Diving Unit (Atlantic) and YMT 12 were detached from Operation Oil, or “Broken Arrow”. The tender made an uneventful passage overnight in calm seas to Halifax Harbour and secured at the Diving Unit in Dartmouth at 0730 on 15 April.

This completed the oil recovery phase of the operation.

COMMENTS, CONCLUSIONS AND RECOMMENDATIONS

For the purpose of gaining experience in a unique operation under somewhat difficult conditions, and as a general test of capability, the whole operation was of great value to the divers. In this connection, it is considered that the opportunity to work in close association with Captain Sven Madsen of Esso International, with his extensive knowledge, sense of humour, and considerable diplomacy was indeed a privilege!

The diving conditions were not too unusual: Canadian naval divers more often than not, are required to work in cold water and cold weather, frequently in exposed locations. However, the ubiquitous black oil, and the duration of the task, made the operation one of a kind.

Of all the lessons learned, the most valuable one is considered to be that there is an adequate potential capability within Canadian resources to cope with practically any salvage operation within reason. However, Operation Oil has exposed the almost complete lack of national organization or preparedness for such a task. The Naval Diving Branch has not been permitted to create a salvage capability, this being considered the exclusive prerogative of the civilian salvage companies. However, it would appear that such companies that may be in existence lack the technical and financial scope and the expertise necessary to undertake a major salvage operation such as the recovery of oil from ARROW. When this lack of capability results in such a far-reaching consequence as the oil pollution of Canso, the costs to these private interests becomes decidedly unrealistic.

The necessary expertise, if not the necessary equipment, can be found in Fleet Diving Units, particularly with regard to underwater operations. There is also undoubtedly a considerable wealth of knowledge available in the naval construction, engineering, and boatswain branches. However, the almost complete lack of readily available basic hardware required for a major undertaking renders all of this expertise relatively impotent.

“Basic hardware” is intended to mean such fundamentals as pumps, ground tackle, anchors, chain and wire cables, buoys, air compressors, flotation equipment, and last but not least, an adequate salvage vessel.

Operation Oil has proven that practically all of the logistic requirements of a full scale operation can ultimately be consolidated on the scene from a multitude of sources within Canada. The majority of the necessary equipment is to be found with the combined resources of the navy and Coast Guard. However, the degree of success which is possible to achieve in such salvage operations is in direct proportion to the rapidity of efficient and adequate reaction.

It follows therefore, that what is basically required is a stockpiling and consolidation of equipment in locations readily available to a task force, together with a contingency plan which will provide the necessary organization and importantly, its rapid utilization.

It is strongly recommended that Fleet Diving Units be a major source of information concerning the details of the required equipment.

It is also strongly contended that Fleet Diving Units must have continuing access to much of the basic hardware which would normally be retained in the previously described depots. This for the purpose of familiarization and training.

In summary, even though the sinking of the tanker ARROW and resultant oil pollution was a major disaster, the subsequent salvage of the remaining cargo provided a unique and valuable experience for diving personnel. It has, particularly with the benefit of hindsight, taught many lessons, and has emphasized a major shortcoming in preparedness for such a disaster. Not to take full advantage of these lessons, by adequately providing for future emergencies, would be at least, regrettable.
METHOD OF DRILLING OF TANKS AND FITTING NECESSARY VALVES FOR HOSE CONNECTION

1. A "nozzle" was especially manufactured with a wide flange at the bottom. This was to enable a vertical positioning of the "COX" gun while firing the threaded studs through the holes of the flange and into the deck.

2. A gate valve was mounted above the nozzle, and the tapping machine attached onto the gate valve. With the gate valve open, the boring bar and cutter were lowered by crank through the gate valve and nozzle, and into contact with the deck. It was then put in gear, and boring commenced.

3. The pilot drill and cutter combination removed a "do-nut" shaped "coupon" from the deck, and retained it on the pilot drill by means of either spring loaded ball bearings, or in some cases an inset ratchet arrangement.

4. After penetration, the boring bar and cutter, with the do-nut retained, were cranked back through the nozzle and gate valve, whereupon the valve was closed, facilitating removal of the tapping machine.

5. Subsequent to the tapping machine removal, a 90 degree elbow was mounted in its place, and the hose attached in turn to the elbow.

6. This procedure is illustrated in Figure 4 of this annex. Both a pneumatic, and a hydraulically operated tapping machine were adapted and successfully used underwater. In the pneumatic machine, the oil in the gear case was changed from SAE 90 to SAE 30 to compensate for the 30°F water temperature. In the case of the hydraulic machine, in addition to the same oil change, several additional modifications were carried out before satisfactory operation was achieved, these were:
   a. the hydraulic fluid was diluted with diesel oil by one third;
   b. some check valves were removed from the hydraulic lines, to provide easier flow;
   c. the gear ratio was lowered; and,
   d. the number of teeth in the cutter was reduced by one half by cutting off every other one, to reduce the load. This was rationalized by the fact that the tapping machine is basically intended for penetrations of the sides of curved pipes, in which case not all teeth would be bearing at once.

7. During the use of these machines underwater, (for which they were not designed) the oil in the gear box became emulsified with water. After about two weeks operation, this oil was flushed out and replaced. No damage to the gears, or the machine generally, appeared to result from this unique application, apart from some slight external corrosion.

8. It was found that the whole assembly, (tapping machine, gate valve, and nozzle) could be readily handled and moved into position underwater when lightened with an air filled 45 gallon oil drum.

9. Drilling into the sides of the tank tops as a means of achieving more complete oil removal was considered and partially attempted, but was not pursued, due to difficulties in achieving a tight fit on the curved surface, and the danger of rupturing the tank top from the deck, through wrenching of the hose. The tank top being constructed of only quarter inch plate. This proposed method is illustrated in Figure 5.
REPORT ON SEINE NET FOR CONTAINING BUNKER C OIL SLICKS

by

H. Douglas Johnston
Regional Representative
Industrial Development Branch
Fisheries Service
Department of Fisheries & Forestry of Canada

for

The Task Force
Project Oil – Chedabucto Bay
March 26, 1970
INTRODUCTION

As the result of the grounding of the Liberian oil tanker M.V. Arrow on Cerberus Rock, Chedabucto Bay, Nova Scotia, February 4th, 1970 a number of bunker C oil slicks have been floating on the surface which pollutes fishing gear, beaches, boats, etc. On March 4th the Task Force appointed to deal with this problem, requested that the Fisheries Service of Canada investigate the possibility of using a net to contain such slicks.

This project was assigned to the Industrial Development Branch of the Fisheries Service on March 4th. On March 20th a net was turned over to Captain M. Martin of the Task Force following two days of successful trials and training of personnel to handle the net.

OBJECTIVE

To construct a seine capable of surrounding and containing a bunker C oil slick.

PROCEDURE

The following steps were necessary to accomplish the objective:

1. Interview herring purse seine skippers who were fishing in Chedabucto Bay and who had encountered oil slicks in the course of fishing.
2. Witness experiments at the Bedford Institute which were conducted in a 15 foot diameter tank using simulated currents, sea water temperature, bunker C oil slicks and fish netting.
3. Construct a net and carry out actual trials in Chedabucto Bay.
4. Engage and demonstrate to experienced fishermen in the area the method of handling the net.

DESIGN

The two main parameters for designing the net were:

1. Use material readily available and
2. Make the net so it could be handled by conventional Cape Island lobster boats which also are readily available.

Prior to designing the net a shut-off net was investigated on Grand Manan Island, New Brunswick. It was found to be much too light i.e. the twine, head and foot ropes and floats. Following this it was decided to construct a net 180 fathom x 5 fathom (see attached drawing). It is made in three sections, each a third of the overall length. The middle section, known as the bunt is made up of 210/21 x 3/4 inch mesh nylon twine while the wings are made up of 210/22 x 5/8 inch nylon twine. A three foot strip of 210/21 x 3/4 inch nylon twine is attached to the head rope and wrapped up over the floats and fastened to the main net. This gives double netting approximately 3 - 4 inches above the water surface, the heighth of the floats.

The 3/8" mesh was chosen as this was the smallest mesh commercially available. The opinion of purse seine skippers, who encountered oil, was that their net (1 1/8" mesh) was suitable for this purpose and tests at the Bedford Institute indicated 1" mesh netting provided a fairly good barrier for bunker C oil slicks.

The depth was selected at thirty feet because:

(a) the tests at Bedford showed that bunkers C when caught in a current submersed quite readily,
(b) the nylon twine netting comes in a standard width of approximately 30 feet,
(c) the foot rope on the net rises approximately 5 feet when being towed and
(d) it was reasonably assumed that the net would set well at this depth.

The length was selected in accordance with the capability of two Cape Island boats towing the net.

TRIALS

The first trial was held in clean water (free of oil slicks) northeast of Green Island, Chedabucto Bay. The boats selected were as follows:

THE "ELDON AND GRAHAM"

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<tr>
<td>BEAM</td>
<td>12 Feet</td>
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<tr>
<td>H.P.</td>
<td>225 (Chrysler Marine)</td>
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<tr>
<td>PROPELLER</td>
<td>3 Bladed 18/22</td>
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<tr>
<td>SKIPPER</td>
<td>George Keating, Rocky Bay, N.S.</td>
</tr>
<tr>
<td>CREW</td>
<td>Gus Keating, Petit De Grat, N.S.</td>
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<td></td>
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<tr>
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THE "BUD AND JACK"

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<tr>
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<td>H.P.</td>
<td>165 (G. M.)</td>
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<td>4 Blade 20/17</td>
</tr>
<tr>
<td>SKIPPER</td>
<td>Raymond Goyette, Arichat, N.S.</td>
</tr>
<tr>
<td>CREW</td>
<td>Hirman Joshua</td>
</tr>
<tr>
<td></td>
<td>Newman Landry</td>
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</table>

It took fifteen minutes to set the net and within fifteen minutes the net was towing in a U-formation with the tide and in the direction of a light wind. Following this both boats turned away from each other, opening the net and finally reversing the direction of towing. This maneuver was accomplished in twenty minutes. The net was then taken on board, each boat hauling in on their respective towing end of the net. Once the net was out of the water and both boats broadside the net was completely landed on one boat, in this case the Eldon and Graham. The net was folded in the boat with floats to the stern and foot rope forward. It took thirty minutes to haul the net out of the water and loaded on one boat. Four men are required on each boat to bring the net aboard.

The net set well and the Cape Island boats were capable of manuvering the net.
sufficiently for containment purposes. They were able to tow the net in U-formation at a very slow rate of speed against the tide and a light wind. The floats extended approximately 3 – 4 inches above water and it was quite evident that the twine which was wrapped over the floats in the bait section would have to extend on both wings the full length of the net. The netting over the floats made an excellent barrier above the surface of the water.

Following the addition of twine on both wings a second trial was conducted and the following persons were in attendance besides the regular crew:

Captain M. Martin — Task Force  
Mr. Des. Dobson — Bedford Institute  
Public Relations Officer — Task Force  
Fishery Officer A. Terrio — Arichat Fisheries Service Office  
Mr. William Pope — Fisheries Service  
Mr. H. D. Johnston — Fisheries Service

The results of this trial were satisfactory and it was the considered opinion of Captain Martin, and others who had seen floating oil for which the net was designed, that the net could successfully achieve the objective of containing and towing bunker C oil slicks.

Captain Martin then met with Mr. Gus Keating and made arrangements for him to look after the net and in the case of an emergency to co-ordinate the use of this net.

With the net trials successfully completed and a trained crew prepared to operate the net, this project was considered finished.

Acknowledgements

(1) Mr. Wm. Pope tech-advisor from the Canadian Fisheries Service I.D.B., Newfoundland who designed, supervised the construction of and carried out actual trials and modifications to the net.

(2) Mr. Gerald Brothers technical advisor from the Canadian Fisheries Service, I.D.B., Newfoundland, who assisted in the design and construction of the net.

(3) The Staff at the Bedford Institute who carried out experiments on the containing of bunker C oil slicks using various mesh sizes of fish netting.

(4) Skippers of purse seiners contacted regarding this matter for their valued opinion.

(5) Mr. Jack Creeper Fisheries Service representative on the Task Force for expediting the development trials.

(6) The entire fisheries service staff at Arichat and specifically Fishery Officer Adrian (Hogan) Arseneault for arranging charters, crew, net loft for modifying the net and in general assisting with development trials.

(7) The Task Force on Project Oil for their interest and confidence.

(8) Mr. John Mortin of the Grimsby Group for his assistance in expediting materials.
1. HEAD-ROPE CONSISTS OF 3/16" SPUN COVERED CORK LINE WITH 12 MESHES HUNG TO EACH 41/2" OF ROPE.

2. FLOAT-ROPE CONSISTS OF 3/8" POLYPROPYLENE WITH FLOATS ATTACHED 8 1/2" CENTERS. (ON BUMP, BUMP PURSE-Seine FLOATS. (5-2 Seine FLOATS) ON WINGS, BODY PURSE-Seine FLOATS. (5-1 Seine FLOATS)

3. FOOT-ROPE CONSISTS OF 3/8" POLYESTER WITH 12 MESHES HUNG TO EACH 41/2" OF ROPE.

4. LEAD-ROPE CONSISTS OF 5/8" POLYPROPYLENE WITH 6 OZ. LEADS ATTACHED AT 12" CENTERS.

5. BREAST-LINE CONSISTS OF 3/16" SPUN COVERED CORK LINE WITH 8 MESHES HUNG TO EACH 41/2" OF ROPE.

6. BRIDLES CONSIST OF 7/8" BRAIDED POLYPROPYLENE ROPE.

7. ALL WEBBING SHALL BE HUNG WITH #30 BRAIDED NYLON TWINE.

8. LASTAGED SHALL BE PUT IN WITH 210 D/15 NYLON TWINE.

9. OVERHANG TWINE LACED ONE MESH BELOW HEADLINE YOKE AND WRAPPED OVER FLOATS EXTENDS 2" - 4" DOWN THE WEB, AND AGAIN LACED TO THE WEB. CARE SHOULD BE TAKEN TO HAVE EACH BAR OF EACH MESH OF THE OVER-HANG TWINE MEET EACH BAR OF EACH MESH OF THE SEINE TWINE HALF WAY.

10. MAIN WARP CONSISTS OF 1" BRAIDED POLYPROPYLENE.

11. ATTACH SWIVELS BETWEEN MAIN WAPPS AND BRIDLES.

VOLUME III

PART 7

REPORT ON DESIGN AND CONSTRUCTION OF SEAWATER FILTRATION PLANT FOR BOOTH FISHERIES
MARCH 1970

Prepared for:
The Operation Oil Task Force

by

CANADIAN PLANT AND PROCESS ENGINEERING LIMITED
Consulting Engineers

Halifax Canada

March 25, 1970

REPORT ON DESIGN AND CONSTRUCTION OF SEAWATER FILTRATION PLANT FOR BOOTH FISHERIES, PETIT DE GRAT, N.S.

INTRODUCTION

On March 6, 1970 a preliminary “Report on investigation of seawater supplies to various fish processing plants affected by the Arrow oil spill”, was presented to the Task Force outlining preliminary laboratory results of experiments using polyurethane as a filtration medium.

Canadian Plant and Process Engineering Limited was authorized to proceed with further laboratory testing and also with the design and construction of filtration systems for the Booth Fisheries plant at Petit de Grat and the Acadian Fisheries (Canco) Limited plant at Canco, Nova Scotia, on the understanding that if alternate sources of supply presented themselves, that work on the project would be stopped. The completion date was estimated as March 31, 1970.

On Sunday, March 8, Dr. McTaggart-Cowan, in a telephone conversation advised Mr. John Jay, President, Canadian Plant and Process Engineering Limited, that an alternate source of supply had been obtained for the Acadian Fisheries plant at Canco and that our efforts should be concentrated on the plant of Booth Fisheries at Petit de Grat.

LABORATORY TESTING

With the cooperation of the Bedford Institute, additional laboratory apparatus was procured and set up under the direction of Dr. Gary Dillon, P. Eng., of the Chemistry Department, Nova Scotia Technical College, retained by Canadian Plant for this project and Mr. E. A. Ross, Civil Engineer of our staff. A complete report of the laboratory experiments, together with photographs of the various materials used and the apparatus, follows.

The preliminary laboratory results reported in our report dated March 5, 1970 indicated a approximate 90 percent removal. We are now pleased to report that various configurations of polyurethane will give 100 percent removal and the design of the filter medium has been changed accordingly.

It is our intention to use a combination of rigid polyurethane chips which are readily available locally as a by-product of the wallboard insulation business, as a preliminary roughing filter followed by a flexible open cell polyurethane die of a Type F14 manufactured by Monsanto in Toronto. This configuration was chosen based on the laboratory results and the low cost of this material.

FILTRATION PLANT DESIGN AND CONSTRUCTION

Design work on the filtration plant commenced on Saturday, March 7th, and had been completed and approved by the Nova Scotia Water Resources Commission by Wednesday March 11th. Materials were procured commencing March 11th with delivery to the site commencing on Tuesday, March 17th. The construction and assembly of the plant with a design capacity of 600 gpm was completed by March 25th and the system readied for operation.
CONCLUSIONS

We are optimistic that the plant as installed by Booth Fisheries will provide a satisfactory solution to the problem faced by the plant if the seawater intake becomes contaminated with oil.

Additional research work should be done in order that this technique can be further refined. The applications are many, with refinery wastes and ships bilge water wastes being two applications which quickly come to mind. The National Research Council and the Bedford Institute have both become interested in this experiment and perhaps they would see fit to continue this research work to a more definite conclusion. We would be pleased to cooperate with either of these groups if we could make a useful contribution.

Our involvement in this phase of the project would now appear to be finished. The filtration plant is in operation a week earlier than anticipated. The budget figure approved on March 6th. has not been exceeded and the subsequent laboratory investigations have improved the performance from the earlier anticipated 90 percent to 100 percent efficiency.

Respectfully submitted,
Canadian Plant and Process Engineering Limited.

JOHN JAY, P.Eng.,
President.

PILOT PLANT INVESTIGATION ON THE REMOVAL OF BUNKER C FUEL OIL FROM SEA WATER

Prepared for

Canadian Plant and Process Engineering Limited Consulting Engineers

Dr. G. B. Dillon, P.Eng.

Halifax, Nova Scotia

March 20, 1970
Introduction

As a result of a request from Mr. J. Jay, President Canadian Plant and Process Engineering, Limited, received on March 10, 1970, a pilot plant study was undertaken to investigate the removal of Bunker C from sea water.

The purpose of these pilot plant studies is three fold:
(1) to determine an effective filter medium for the efficient removal of Bunker C from sea water.
(2) to determine design data for scale up to a plant size filter.
(3) to develop an analytical technique for the determination of Bunker C in sea water.

With the assistance of the Bedford Institute of Oceanography a pilot plant model was completed on March 19, 1970 and housed at B.I.O. (See Figure 1. Appendix 1) Analytical techniques were developed with the assistance of the National Research Council. (See Appendix 11).

2. Pilot Plant (General)

In the construction of the pilot plant the following design criteria were considered:
(1) capability of handling approximately 10 gal/min ft² of filter (Based on an anticipated plant intake flow rate of 600 gal/min.).
(2) capability of gravity feeding the filter.
(3) simplicity of design for ease of operation and maintenance.
(4) allowance for both continuous and batch operation.

Previous experimental studies carried by Canadian Plant and Process Engineering Ltd. (A report on the removal of Bunker C fuel oil from sea water March 5, 1970), indicated that the use of rigid and flexible polyurethane chips presented an effective method of Bunker C removal. Thus in the construction of the pilot plant filter a design was adopted whereby both chipped polyurethane as well as continuous polyurethane pods could be investigated as a filter medium. A detailed description of the pilot plant is included in Appendix 1.

3. Pilot Plant Investigation

A series of eight (8) runs was carried out which allowed for investigation of various filter medium arrangements as well as methods of operation. Three types of polyurethane were investigated.
(1) Rigid polyurethane chips (approximately 1” - dia.).
(2) Flexible polyurethane chips (approximately 2” cubes).
(3) Flexible polyurethane discs (20” dia - 4” thick).

Both continuous and batch operations were undertaken with combinations of the above three types of filter medium. The following table outlines these combinations and method of operation.

<table>
<thead>
<tr>
<th>Run No.</th>
<th>Method of Feed</th>
<th>Filter of Medium</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Batch</td>
<td>48” of flexible disc (12 discs - 4” thick).</td>
</tr>
<tr>
<td>2</td>
<td>Continuous</td>
<td>26” of filter medium 1-4” disc at bottom of filter. 22” of rigid polyurethane chips. 50 cc of creosote added to feed makeup.</td>
</tr>
<tr>
<td>3</td>
<td>Continuous</td>
<td>48” of filter medium 1-4” disc at bottom 44” of rigid polyurethane chip.</td>
</tr>
<tr>
<td>4</td>
<td>Continuous</td>
<td>48” of filter medium 1-4” disc at bottom 44” of flexible polyurethane chip.</td>
</tr>
<tr>
<td>5</td>
<td>Continuous</td>
<td>48” of filter medium 1-4” disc at bottom 4-4” of flexible polyurethane chip.</td>
</tr>
</tbody>
</table>

4. Experimental Techniques:

Batch operation: 220 gals of sea water were added to the feed storage tank along with a sufficient quality of Bunker C to give a representative concentration level of Bunker C in sea water at the intake to the filter. Samples at the intake and outlet of the filter were withdrawn at regular time intervals and analyzed for Bunker C. Outlet water from the filter was sewered.

Continuous operation: A similar procedure was adopted as in the batch operation except that outlet water from the filter was returned to the feed tank. This enabled a longer run time. Sampling was carried out as above.

Results (Pilot Plant): The following table summarizes the results for the eight runs.
<table>
<thead>
<tr>
<th>Run No.</th>
<th>Time (Mins)</th>
<th>Flow Rate gal/min</th>
<th>Flow Rate gal/min ft²</th>
<th>Plant #</th>
<th>Flow Rate gal/min</th>
<th>Fluid Temp</th>
<th>Fluid # head in.</th>
<th>inlet</th>
<th>ppm oil outlet</th>
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<td>18.4</td>
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<td>660</td>
<td></td>
<td>37</td>
<td>4</td>
<td>0.0</td>
<td>No Detectable oil in inlet samples (See discussion)</td>
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<tr>
<td></td>
<td>2</td>
<td>18.4</td>
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<td>660</td>
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<td>&gt;550</td>
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<th>Flow Rate gal/min</th>
<th>Flow Rate gal/min ft²</th>
<th>Plant #</th>
<th>Flow Rate gal/min</th>
<th>Fluid Temp</th>
<th>Fluid # head in.</th>
<th>inlet</th>
<th>ppm oil outlet</th>
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Note (1) No visible head above chips

# Fluid Head measured with reference to top disc in filter

## Based on equivalent loading with 10 ft. dia. filter
5. Discussion

The operation of the pilot plant filter utilizing various filter medium combinations and gravity feeding indicated that in all cases except run 3 removal of oil was carried out. In the case of run 3 a dispersal agent “Correxit” was added to the feed tank. This caused a breakup of the Bunker C into small particles which appeared in the filter outlet. However it should be observed (Table 2) that a very high inlet concentration of Bunker C was present (> 558 ppm). At this high concentration level the filter was able to remove 97 percent of the inlet oil.

Run 1 is included in the table of results. No detectable oil was found in Run 1 since an insufficient quantity of oil was added to the feed tank. However this run does indicate the head attained prior to any oil deposition on the filter medium. It can be seen that even after three further runs (approximately 600 gals of feed) no detectable increase in head occurred even though the top filter disc was heavily coated with oil. (See photograph Appendix III). Upon removal of the top disc no detectable oil was observed on the second disc indicating a high removal rate per disc.

In the use of both polyurethane chips and disc it was observed that a large amount of the oil was deposited on the chips with no detectable oil appearing in the outlet.

Conclusion and Recommendations:

1. Polyurethane was found to be an effective filter medium for Bunker C removal of sea water.
2. Continuous flexible polyurethane was found to be the most effective form of filter medium.
3. Complete removal of Bunker C was observed in all cases except in the presence of dispersal agent (with Correxit 97% removal). The loading rate was equivalent to actual plant conditions 10 gals/min-ft².
4. Gravity feed system possible.
5. A combination of 3-4 feet of rigid polyurethane chips with 4-8 inches of continuous flexible polyurethane on the bottom of the filter appears to be the most effective combination of filter medium.
6. No detectable smell of Bunker C was observed in those runs which indicated complete removal.
7. The feasibility of “in plant” foaming of the continuous layer be investigated. It is also suggested that the bagging of any chipped material to be used as filter medium, be investigated. This would allow for quick and easy removal of spent filter medium.

APPENDIX I
APPENDIX I

Pilot Plant Apparatus:

The pilot plant filter was located at the Bedford Institute of Oceanography and consisted of a 6 foot - 20 inch diameter filter fitted with a false screen bottom and a flanged top. Mild steel was the material of construction. A fibre glass tank of 275 gal capacity was used to store sea water drawn from the Bedford Basin. Sea water was withdrawn from the tank and fed to the filter by means of centrifugal pump. A by pass on the pressure side of the pump provided for the return of feed stock to the tank or sewer. Filtrate was removed from the bottom of the filter by means of a 4 inch plastic line fed either to sewer (Batch operation) or to the feed tank (Continuous operation).

A 1 \( \frac{1}{4} \)" sample line fitted with a valve was provided at the base of the filter. Mixing of the feed tank was maintained by blowing air through a perforated ring at the bottom of the feed tank.

See Figures 1 and 2 for details of the apparatus.
Analysis of Bunker C in Sea Water:

Sample Collection:

Samples of the inlet and outlet of the filter were collected for the determination of inlet oil concentration and the residual outlet concentration. The sample size varied from 290 - 350 cc.

50 cc. of chloroform was then added to the sample and shaken thoroughly to insure mixing of the chloroform and Bunker C. The chloroform - oil layer was then withdrawn using a separatory funnel. A further 50 cc. of chloroform was added in two 25 cc. lots to insure complete removal of the oil from the sample collection vessel. The weight of oil contained in the 100 cc. of chloroform was then determined using a Fisher Fluorescence Spectrometer. This weight was then related to the ppm of oil contained in the sample.

Preparation of Standards:

Standard concentrations of Bunker C in chloroform were prepared and used for the preparation of a calibration curve relating percent transmittancy versus grams of Bunker C/100 cc. of chloroform. See figure 3.

The spectrometer was used in its most sensitive range (x.001).

The instrument with the dilution factor used (100 cc.) was found to be sensitive down to 0.5 ppm of Bunker C in sea water.
LIST OF ILLUSTRATIONS

FIGURE 1. — Laboratory equipment showing mixing tank, pump, lower portion of filter, drain line, and effluent sample line.

FIGURE 2. — Laboratory equipment showing filter vessel.

FIGURE 3. — Top polyurethane disc after runs 1 to 4

FIGURE 4. — As figure 3 in section.

FIGURE 5, 6, & 7. — Test run 5, showing rigid polyurethane chips and polyurethane disc supporting the rigid chips.

FIGURE 8, 9, & 10. — As above for run 6.

FIGURE 11, 12, 13, & 14. — Flexible polyurethane chips and flexible polyurethane disc utilized in run 7.

FIGURE 15 & 16. — Polyurethane disc used in run 8.

FIGURE 17. — Polyurethane discs with laboratory test runs indicated.
Ferguson Industries Ltd., Pictou Nova Scotia Drawing No. 3000-1538, dated 1/4/70:

FISHING GEAR LAUNDROMAT POWER BLOCK SEATING Drawing No. 3000-1517, dated 3/4/70:

FISHING GEAR LAUNDROMAT

PLANS FOR FISH GEAR LAUNDROMAT
VOLUME III

PART 9

REPORT ON ABSORBENTS

Report on activities in Chedabucto Bay
and on related research conducted
at the university of Sherbrooke

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### Acknowledgment

I wish to express my most sincere thanks to Dr. W.D. Jamieson, assistant to the Director of the National Research Council, Atlantic Laboratory for his cooperation. Without his help the field tests conducted in Chedabucto Bay would not have been possible. I wish also to thank Mr. Norman Sellar and Mr. Walter Crosby for their help in carrying out the experiments.
I Introduction

Following the wreck of the tanker Arrow in the Bay of Chedabucto in February 1970, I had the opportunity to carry out some field tests on the site of the oil spill. Controlled experiments were also conducted in Sherbrooke both at the University and nearby locations. The present report is divided into two parts and will cover both activities.

II Field Tests Conducted in Chedabucto Bay

On February 16, 1970, a call from Dr. W.D. Jamieson, assistant to the Director of the National Research Council, Atlantic Laboratory, informed me of the possibility of carrying out some experiments with peat moss in the Bay of Chedabucto. My research assistant, Mr. Francois d'Heurenezel and I left Sherbrooke on February 17th and were in Arichat the following day. With the help of Mr. Norman Sellars, Dr. Jamieson's technician, tests were conducted on the shores of Janvrin Island. The following day a boat was rented and an experiment on open sea was performed. On February 25th, I came back to Arichat and a controlled experiment with sawdust, straw and peat moss was scheduled. Finally in the first week of March, mixtures of bunker and peat moss were used for burning experiments under various conditions.

All the field tests were planned and carried out to assess the potential of peat moss as absorbent. Previous research conducted under laboratory conditions had shown that peat moss selectively absorbs oil and repels water. (1) Field tests were however necessary before reaching any conclusion.

a- Tests conducted on February 18, 1970

The site of the field tests was the northern shore of Janvrin island. The weather was mild and the temperature in the lower fifties. In the first experiment, a patch of oil of approximately 20 square feet and moving simply to the shore was spread with peat moss and left for thirty minutes. Using a ½ wire mesh screen, two persons brought the slack to the shore by dragging it with the screen positioned vertically in the water. The mixture peat moss-bunker C did not stick to the screen and once ashore it was molded into a sphere.

The second experiment was conducted in the following way. The same screen was positioned vertically in the water (3 feet deep) and acted as a boom. Peat moss was spread ahead of the screen and a patch of oil was easily stopped by the boom. Finally in the last experiment, peat moss was spread on the shore and oil from the sea came and covered it. It was then easy to rake the beach and collect the mixture.

b- Tests conducted on February 20, 1970

The experiments were conducted on Janvrin island under severe weather conditions. The temperature was in the twenties and snow and ice had packed all along the shoreline.

The first experiment was planned to be performed on rather large oil slicks in order to fully test the absorbency of three materials: sawdust, peat moss and straw. Due to extreme cold weather of the previous days, it was impossible to find patches unmixted with ice and snow. After considerable search, it was finally decided to carry out experiments on oil patches exposed at low tide.

Three patches of about 5 ft² were chosen. One was covered with sawdust, the second one with peat moss and the last one with straw. The quantities used were two bags of sawdust (100 pounds), two bales of straw and two bales of peat moss. The sawdust was dry and had been brought to the site from Truro. The straw was provided by Imperial Oil and the peat moss was the commercial type used for soil amendment.

After thirty minutes, each patch was examined. The sawdust had not even stuck to the oil surface. The peat moss had stuck to the surface and the mixture could be gathered up and be shaped into a sphere without any adherence to the gloves. As to the slick covered with straw, the adherence was less and the collecting was more difficult. It is however necessary to point out that the material was no longer bunker C oil because of its long exposure to the water and to cold weather. The mixture was of the grease type and it was impossible to assure that absorption was taking place.

In the second experiment, burning was tried. To ignite the mixture, a turbo fuel was used as a starter. For the three patches, the experiments were negative. Additional tests or burning will be discussed later.

c- Experiments conducted on March 1, 1970

The experiments took place on Cape Auget where heavy patches (2 thick) of bunker C oil was exposed to low tide. The tests aimed at trying to burn the deposits on the shores. Chemicals as sodium perchlorate, ammonium nitrate, metal oxide as SiO were used.

Peat moss was spread on the patches and seemed to act as a wick. The fire was started with gasoline. Burning did occur at the beginning, but the combustion was not self-sustaining. After ten minutes the fire died out. The degradation of the bunker with time and its long exposure in water are certainly two major factors. Tests were conducted at the University of Sherbrooke on a mixture 60% bunker, 40% water left outside during February for twelve days and the combustion was performed completely with only peat moss and gasoline.

d- Experiments conducted on February 19 and March 2, 1970

It was planned to assess the possibility of gathering oil slicks on the sea. On February 19th, a boat was rented and an experiment conducted on open sea. Before leaving the docks a boom was built with ½ mesh wire screen. The boom was twenty feet long and five feet high. Floats were fixed to the net in order to assure floating, while a chain was used as lead weight. A piece of wood was also attached to the net in order to keep the net from curving.

Once on the boat, a slick was found and ten bales of peat moss spread by hand. Here the modified snow blower would have been very useful. The boom was pulled by the boat and the recovery was very poor because the boat first divided the slick into two parts and the boom did not gather anything. On March 2nd, the same net was used but pulled by two boats. The collecting was then much more successful, even if the weather conditions were severe (wind, snow, waves).

e- Tests conducted on April 22, 1970

On our way to Arichat, my research assistant and I were told to go to Glace Bay and look at the beaches polluted with bunker C oil resulting from the sinking of the Patrick Morris. Once there, we visited a beach located between Glace Bay and Tonkin. The beach was spotted with numerous lamps, approximately one square inch in size. Ten men from CNR in Sydney were taken to the beach in order to proceed to the cleaning. Peat moss was spread on the beach, and mixed with the oil with the rakes. The mixture was then raked and put in 45 gallon drums. The operation was successful and peat moss was kept in nearby locations for possible future uses.

III Conclusions

Even if the number of experiments is by far very small, qualitative conclusions can be reached.

1. Peat moss behaves on the sea the way it has been found to behave in the laboratory. The first experiment seems to indicate that peat moss could be very useful in collecting oil slicks on the sea.
In case of oil in the shores, the hazards could be eased by previously spreading peat moss. This operation would facilitate the collecting operation.

3- Exposure to weather conditions and sea water degrades the oil and it becomes more and more difficult to absorb it. The absorbency of peat moss is rather quickly decreased as the oil changed from its regular state into a rather grease type material.

4- Beach cleaning is "relatively" easy with peat moss. Raking the peat moss and the bunker C provides mechanical energy which increases the absorption. The mixture does not stick to the rake and the technique is valid where raking is possible. On rocky shorelines, other techniques have to be experimented. In the second part of the report, a controlled experiment conducted nearby Sherbrooke will be discussed.

IV Laboratory Research Conducted at the University of Sherbrooke

Dr. Alan Young McLean from the CleanUp Technology group asked me to test the absorbency of some materials. Peat moss, silicone material, absorbent type C and a packing material were tested. The peat moss and the absorbent type C were extensively tested while a few experiments were made with the other materials. Emulsions of water and bunker C were made and mixed with either peat moss or absorbent type C in order to measure the influence of the water content on the absorbency.

a- Absorbency of peat moss and absorbent type C

i- Experimental procedure

The technique used was identical to the standard method of test for oil absorption of pigments by Gardner-Coleman method (2), except that it was conducted in two different ways. In the first method referred as method 1, a given amount of material (5 grams weight) was transferred in a stainless steel cup and the amount of mixture of bunker C oil and water was added at a very slow rate. Stirring with a spatula was achieved during the addition. As the particles of the absorbent became wetted, they collected in small lumps which gradually coalesced. The end point was reached when the lumps had collected into a single lump.

On the second technique referred as method 2, a given amount of mixture was placed in the container and the absorbent material was added. It was found that the test conducted in this way was more suitable for both the peat moss and the absorbent type C.

The results are related to the technique used. We made a survey of the methods available and found the Gardner-Coleman method the most suitable one, because it provides mechanical energy (stirring action) as we might expect on sea (wave action) or on land (raking).

The mixtures of bunker C oil and (percentage by weight) water were made in different ratios. For each mixture, agitation was achieved in order to make mixtures as homogeneous as possible.

ii- Calculations

The absorbency was calculated on a mass basis according to the following equation.

\[ \text{absorbency} = \frac{\text{grams of mixture absorbed}}{\text{grams of absorbent}} \]

iii- Results

The results are given in Table 1 for peat moss and in Table 2 for the absorbent type C. Figure 1 shows the results in a graphical form. For peat moss, for a water content higher than 40%, the selective absorption is clearly observed. First, oil is easily absorbed and then water. For mixtures higher than 70% of water, tests were difficult to conduct and reproducibility was poor. Tests were made with fresh bunker C oil and tap water, and the emulsions were very much different from what was found on the shores of Chedabucto Bay. Dr. McLean sent us a sample and a test has been carried out with it. The mixture was semi-solid and very viscous. The figure from the test gave 13.9 grams of mixture "absorbed" by gram of peat moss used. This value gives a water percentage of 40% according to the curve given in figure 1. Simultaneously a sample was heated at 220°F and kept at this temperature until the sample experienced no change in weight. The water content was calculated at 40%. The results show that a maximum in absorbency is reached for a water percentage of around 40%. It is difficult to advance any explanation but there is certainly an interaction between the bunker C oil and the water. Some samples of dried and wet (40% water) peat moss were studied with an electron microscope by my colleague, Dr. Maurice Ruel. The material is made up of very long pores and it has been observed that the addition of water up to a certain quantity enlarges the diameter of the pores. Beyond that point water fills the pores completely and selective absorption takes place. Figures 2 and 3 show two pictures of a pore observed with an electron microscope.

The absorbent type C sold by Cleanwater Inc. show a constant absorbancy versus the amount of water in the emulsion. The density of absorbent C was measured and found equal to 0.0655 while the figure for peat moss is 0.0855. It is then not better than peat moss on a volume basis. The absorbent type C is more expensive than peat moss and does not present any economical advantage. Since it is not inflammable, the mixture oil-absorbent cannot be burnt.

b- Absorbency of packing material, eelgrass, pine needles and synthetic fibres

i- Experimental procedure

In order to measure the absorbency of those materials not available in granular form it was necessary to use a different technique. The method consisted in immersing a given weight of the material into the oil for a given amount of time, pulling it out and leaving it until dripping stops. By weighing the sample before and after the immersion, the absorbency was then evaluated. The sample was put into a cylinder of 8 in diameter and 2" in height, made of a stainless steel wire mesh. The cylinder was weighed (M1) and then submerged into the oil and weighed again (M2). The difference (M2 - M1) gave the amount of oil "retained" by the cylinder. The sample under study was placed into the cylinder and weighed (M3). The cylinder is then immerged in the oil for thirty minutes (found to be saturation point) and pulled out and allowed to drip for three and a half hours, and weighed (M4). The weight (M5) was measured before each test, because it changed with the number of experiments. Oil in a semi-solid phase coated the mesh.

ii- Calculations

The different weights are used to calculate the absorbency according to the equation:

\[ R = \frac{M_5 - M_4 - (M_2 - M_1)}{M_2 - M_1} \]

iii- Results

The results are presented in Table 3. The synthetic fiber gives a very good absorbency but it is far from the specifications (20 - 30 times its weight). It would be necessary to know the method used and the type of oil in order to fully establish a comparison because of lack of data.

c- Effect of temperature and salt water on absorption

The temperature is an important variable because it affects the viscosity of the oil. The higher the viscosity, the slower is the rate of absorption. For bunker C oil, the viscosity at 70°F was measured with a Brookfield viscometer and found equal to 15,000 centipoises. In the Bay of Chedabucto the temperature of some oil slicks were measured and found in the lower thirties. At such low temperature, the bunker C oil becomes a semi-solid and absorption is very slow.
Table 1
Absorbency of peat moss

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Method 1</th>
<th>Method 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunker C - water</td>
<td>g of mixture absorbed</td>
<td>g of oil absorbed</td>
</tr>
<tr>
<td>%H₂O</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>7.7</td>
<td>8.2</td>
</tr>
<tr>
<td>10</td>
<td>9.6</td>
<td>9.8</td>
</tr>
<tr>
<td>13</td>
<td>11.2</td>
<td>12.5</td>
</tr>
<tr>
<td>25</td>
<td>14.6</td>
<td>15.2</td>
</tr>
<tr>
<td>33</td>
<td>14.9</td>
<td>15.8</td>
</tr>
<tr>
<td>40</td>
<td>15.8</td>
<td>16.8</td>
</tr>
<tr>
<td>50</td>
<td>14.8</td>
<td>13.8</td>
</tr>
<tr>
<td>60</td>
<td>14.0</td>
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<tr>
<td>70</td>
<td>12.8</td>
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<tr>
<td>80</td>
<td>13.4</td>
<td>14.1</td>
</tr>
<tr>
<td>100</td>
<td>10.0</td>
<td>10.4</td>
</tr>
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</table>

Table 2
Absorbency of absorbent type C sold by Clearwater Inc.

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Absorption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bunker C - water</td>
<td>%H₂O</td>
</tr>
<tr>
<td>%H₂O</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>6.01</td>
</tr>
<tr>
<td>10</td>
<td>5.95</td>
</tr>
<tr>
<td>20</td>
<td>6.15</td>
</tr>
<tr>
<td>35</td>
<td>5.25</td>
</tr>
<tr>
<td>55</td>
<td>6.50 (1)</td>
</tr>
<tr>
<td>75</td>
<td>not measured (1)</td>
</tr>
<tr>
<td>100</td>
<td>not measured (1)</td>
</tr>
</tbody>
</table>

Test concluded with sample from Chedabucto Bay: 6.57
(1) Since the absorbent does not absorb water it was impossible to measure for water content higher than 53%.
Figure 2. Sample of peat moss observed with an electron microscope
enlargement: 14,000

Figure 3. Sample of peat moss observed with an electron microscope
enlargement: 66,000
Table 3

<table>
<thead>
<tr>
<th>Material</th>
<th>M₁</th>
<th>M₂</th>
<th>M₃</th>
<th>R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eelgrass</td>
<td>1.285</td>
<td>1.318</td>
<td>1.475</td>
<td>6.2</td>
</tr>
<tr>
<td>Pine needle</td>
<td>1.290</td>
<td>1.313</td>
<td>1.425</td>
<td>3.3</td>
</tr>
<tr>
<td>Absorbing fiber from</td>
<td>1.295</td>
<td>1.308</td>
<td>1.475</td>
<td>11.7</td>
</tr>
<tr>
<td>Collins and Atkinson (30&quot; x 18&quot; piece)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial peat moss</td>
<td>1.295</td>
<td>1.397</td>
<td>2.090</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Emulsions with salt water were made and absorption tests conducted. The results did not differ from the figures determined with fresh water.

d. Experiment conducted on rocky shoreline

During my last visit to the Bay of Chedabucto, I noticed large rocks exposed at low tide and completely covered with bunker C oil. The layer was semi-solid and seemed stable at the prevailing temperature. There is however no doubt that the oil will flow back to the sea during the hot summer days.

A controlled experiment was then scheduled in Sherbrooke in order to test a technique of steam cleaning followed by an operation of recuperation.

A farmer in the country nearby Sherbrooke agreed to rent us part of a stream located on his land. Half submerged rocks located in the stream were then covered with bunker C oil and booms were installed at proper locations in order to prevent the oil from polluting the remaining of the stream. A steam jenny, a portable mud pump and steam generators were brought up on the site of the experiment. Peat was spread on the rocks which were then steam cleaned using the steam jenny. The bunker C oil flowed down the rocks and combined with peat moss. Additional quantity of peat moss had been placed ahead of the boom. The current brought the bunker C oil and the peat moss to the boom where everything was stopped. With the mud pump we succeeded in recuperating the mixture. The technique did work for large rocks but is certainly not very rapid. Figure 4 shows a sketch of the operation.

V. General Conclusions

From what I have seen in the Bay of Chedabucto, the best plan is to remove the oil entirely from the water. This may be done by spreading material on top of the oil which absorbs it and forms a mass which may fairly easily be removed from the surface of the water. The use of this method in open water must be facilitated by proper installation of booms and barriers. A good absorbent must possess good properties as regards sucking up oil and in addition it must be able to remain afloat sufficiently long on the surface of the water, so that the mixture it forms with the oil may be removed before it sinks.

The first of these conditions is exceptionally well fulfilled by peat moss. As far as the second condition is concerned an air-dried peat to approximately 35% water content is very suitable. Commercial peat moss sold in plastic bags is dried to that extent. Regarding smaller disasters arising from oil it would be quite possible to keep bales of peat moss in harbours and other suitable places, where oil is handled in great quantity. For crude and any lighter oil, the absorbent by peat moss is very fast and the absorbency may go up to twice the absorbency of straw. It should be possible by using peat as absorbent agent to prevent industrial oils and oils used by garages from getting into our waterways by way of the ordinary sewers.

For bunker C oil at temperatures prevailing in the winter in Chedabucto Bay, the first hours were crucial. The bunker C changed from its regular state into a semi-solid water in oil emulsion. Any absorbent including peat moss is not very effective after a certain time.

Sandy beaches polluted by oil can be relatively easily cleaned with peat moss. The operation is efficient and must be done as soon as possible, following the spill and thus preventing oil from getting into the soil. According to Swedish estimates, 60% of the entire amount of oil handled in Sweden goes into the soil. This would mean, as far as Sweden is concerned, a quantity of 2 - 4 millions of pounds of oil getting into the soil every year and contaminating the ground water. On rocky shorelines, the only technique I have experimented consists in steam blasting followed by the recuperation of the mixture formed by an absorbent and the oil.

From an economical point of view, the use of peat moss as absorbent is very
of temperature and the importance of the moisture content of peat moss on the absorbency of peat moss.

Moreover I am currently conducting a comparison of the relative effectiveness between various products together with relative costs. Such a study should be carried out both under laboratory and field conditions (5).

VI  Future Work

Disasters similar to the sinking of the tanker Arrow are more and more possible because the volume of the oil handled every year increases. Research should be continuously carried out in the field of oil spill cleaning. Collecting techniques and boom technology should be two important research avenues and cooperation should be established with people already active in the field (3, 4). Peat moss as absorber certainly presents many advantages. Field tests under different conditions should be conducted in order to find the most efficient technique. Sweden in particular is very active in the field and they found that peat moss is a very good "aid" in oil cleaning techniques (4).

Personally I am now deeply concerned by the problem. My research assistant, Mr. Francois d'Henniez is currently undertaking a complete statistical design of experiments in order to assess the influence and the interaction of the nature of the oil, the influence
References


2. ASTM - D1483-60.


5. Mr. H. Bernard, United States, Department of the Interior.

VOLUME III

PART 10

REPORT ON SLICK LICKERS
THE SLICK LICKER

Its Origin, History, Manufacture and Employment in Chedabucto Bay, N.S.

By: R. B. H. Sewell

INTRODUCTION

Operation OIL provided the opportunity to demonstrate the fact that the “oleovator” otherwise known widely as the “Slick-Licker” and the “Oleovator” could pick up the very high viscosity fuel oil from the tanker “ARROW” which was floating in various areas around Chedabucto Bay. The presence of large quantities of seaweed and other accumulated seaweed materials complicated the pick-up job and made minor modifications to the first “Slick Licker” on-site desirable.

The origin, history, and employment of the “Slick Licker” will be dealt with in that order below:

Origins

The “Oleovator” had its beginning in a request from the Office of the Command Technical Officer and the Command Fire Chief of the then RCN to the Pacific Naval Laboratory (which has since become the Defence Research Establishment (Pacific) of the Defence Research Board) for assistance in the development of a system to deal with oil spills which resulted primarily from the transfer of petroleum products, mainly fuels in Esquimalt Harbour.

Consideration of the problem made it appear that the system should consist of two main elements. These being (1) a floating boom with pendant skirt (which could be inflated) for containment and (2) a device for picking up the oil thus contained from the water surface. As the boom was being made under CTO authority, the laboratory effort was confined to oil pickup.

It finally occurred to the writer that a system based on preferential wetting might have something to offer.

This model worked well and was able to produce a very clean separation of oil from water. The range of oils covered ran from light diesel oil to Bunker C.

This part of the work was described in Pacific Naval Laboratory Materials Report 61-B entitled “Absorption Device For The Removal of Flammable Spills From Water Surfaces” by R.B.H. Sewell” resulted in the issuance of Canadian Patent No. 735254 entitled “Device and System for Handling Spill”.

Following the Torrey Canyon grounding, it was decided by the Director General of the Defence Research Establishment Pacific (Mr. P. F. Chinnick) that the production of a full scale working model be undertaken. The work was largely completed by early 1969 and trials of this machine ashore at the Damage Control School Colwood V. J. B. C. were undertaken in March 1969. Further trials were undertaken in Esquimalt Harbour in April 1969. The trials appeared to bear out the expectations engendered by projections based on the results obtained with the laboratory scale model. This work is briefly described in DREP Materials Report 69-J and is entitled “A Full Scale Device For The Removal of Oil From Water Surfaces”.

Following these successful trials, the machine (Slick Licker) was placed in storage.

A short time later, Canadian Patents and Development Ltd., licensed a company known as R.D.I. Cyanurates Patents and Processes Ltd. of P.Q. Box 803, Postal Station “A”, Victoria, B.C. to manufacture and sub-license the manufacture of “Oleovators” now widely known as “Slick Lickers” throughout the world. This company had produced and
demonstrated second generation “Slick Lickers” and was in the process of completing a third when a call from Dr. H. Sheffer V/C D.R.B. of the “Operation Oil” Task Force was received at the Defence Research Establishment Pacific in the latter part of February, 1970. Dr. Sheffer requested that immediate steps be taken to determine whether or not the DREP developed “Slick Licker” could pick up at a significant rate bunker fuel of the viscosity carried by the tanker “ARROW” from a water surface.

The requested trials were undertaken on March 4, 1970, successful trials using Gulf Bunker 6 fuel oil on water cooled to approximately 32 - 33°F. by the use of three tons of ice were completed at the Damage Control School, Colwood, V.I., B.C.

Dr. Sheffer then directed that the machine (Slick Licker) be brought to Chedabucto Bay. For various reasons including weight of the machine, length of belt, etc., it was deemed that the DREP machine would be unsatisfactory. Arrangements were therefore made on a “no strings attached” basis for the loan of a second generation “Slick Licker” from the above mentioned company.

The borrowed machine was flown by Canadian Forces Buffalo Aircraft from Vancouver, B.C. to Sydney, N.S., where it arrived the evening of March 10, and was transported to Port Hawkesby, N.S. by truck on the morning of March 11, 1970. On Thursday, March 12, 1970, the “Slick Licker” was placed on board a 27 foot self-propelled barge (S.P. barge) and a plywood box was built to hold about 45 gallons of material. On Friday, March 13, 1970, the barge with Slick Licker aboard was towed to the inside of a small jetty about three miles west of Anchort. Shortly after arrival, the “Slick Licker” engine was started, the clutches engaged and very shortly the wooden box consumed 45 Imperial gallons of viscous oil well loaded with sea weed. No accurate determination of delivery rate was possible here as the matter was picked up in several bites. Dr. H. Sheffer of D.R.B. attended this demonstration.

On Sunday, March 15, 1970, another demonstration of the “Slick Licker” was put on in “The Basin”. On this occasion, the pick up end of the machine was dipped into a mixture of oil, seaweed and ice. So much material was picked up that the twin V-belts in the drive began to slip. Again, no meaningful measure of pickup rate was obtained as the operation period was uninterrupted. However, this second demonstration again showed that the machine could pick up almost anything. Dr. P.D. McTaggart-Cowan, Dr. H. Sheffer and Captain M. Martin attended this demonstration.

The following day (Monday, March 16, 1970) the Task Force decided that three “Slick Lickers” in all would be required and that construction of these machines should be done locally. It was also decided that the borrowed machine should be modified to allow it to unload directly into 45-gallon drums and that more idler rollers to provide greater belt support should be added and a more positive method of drive provided.

Manufacture of Machines

Investigation of the facilities at the Port Hawkesby Shipyard Ltd. showed that the machines could be built there. A sub-license agreement to manufacture “Slick Lickers” on a royalty free basis was arranged accordingly between R.B.H. Cybernetics, Patents and Processes Ltd., of P.O. Box 4205, Postal Station “A”, Victoria, B.C. and Canadian Patents and Development Ltd. of Ottawa, Ontario and The Port Hawkesby Shipyards Ltd. of Port Hawkesby, N.S.

Orders were placed for all the materials deemed to be required for the construction program. As can be imagined, a large part of the materials and components required had to be brought in from other cities. The delays encountered with some of the deliveries were considerable.

In general, the shipyard staff did very well with the (to them) entirely new problems posed by this manufacturing program.

By April 1, 1970, the modifications to the original “Slick Licker” had been completed to the extent they could, pending delivery of new clutches, sprockets and chain for the positive drive. In other words, the new idler rollers had been added and the frame height increased to allow unloading directly into 45 gallon drums (a very successful trial of the machine on S.P. barge was held off Rabbit Is. on April 1, 1970 when several drums of heavily oiled seaweed were picked up. One of these drums was filled in a minute—however, V-belt slippage occurred when water and oil got on the V-belt pulleys). The first of the new third generation “Slick Lickers” which had been completed on April 7, 1970 was run in on April 8 at the shipyard and was put aboard one of the 27 foot S.P. barges.

The second new machine was completed on Sunday, April 12, 1970, and the third new machine was ready for shipment on Saturday, April 18, 1970.

Employment of the Slick Lickers

As developed, the basic units (four in number) consisted of a barge (or catamaran) on which was mounted a Slick Licker (Olelevator) accompanied by an LCM equipped with cargo handling gear.

The Slick Lickers delivered the picked up oil, oil plus seaweed or oil plus everything into 45 gallon drums which were furnished with polyethylene liners. When a Slicker carrying barge had filled its stock of drums, these would be transferred to the accompanying LCM. New drums would be picked up as part of the exchange. The picked up material was delivered by truck to selected sites.

The whole “Slick Licker” fleet was divided initially into two squadrons, each made up of two “Licker” units. These were dubbed the “North” and the “South” Squadrons, and were under the commands of Captains Greenham and Stuart, respectively.

Most of the work done by this fleet was (and is) by the nature of things around Chedabucto Bay, at the time they came on the scene, confined to working very close inshore (The S.P. barges on which three of the “Lickers” are mounted and the catamaran on which the fourth machine is mounted are well suited to this requirement).

Since much, if not most, of the material picked up by the “fleet” was (and is) oiled seaweed, some guiding of the oiled weed to the pick end of the “Licker” conveyor was (and is) required.

The particular nature of this enterprise is well illustrated in the photograph.

Conclusions

i) The “Slick Lickers” were in the right place at the right time.

ii) The performance of the machines at the date of writing (April 28, 1970) seems to have been good and their teething pains minimal (two clutch adjustments, one belt change and one broken roller on the original machine plus a broken cable on the belt frame angle controlling system).

iii) The effectiveness of the combination of preferential wetting for separation plus conveyor materials handling seems evident on the basis of the Chedabucto Bay work.

Future Work

The untitled regions here are great. Some of them are:

i) Addition of heat sources through enclosure either of the “Slick Licker” or of the platform on which it rests to allow effective use in the Arctic or other not well heated regions.

ii) In-plant applications (of which there should be several) Refinery applications are being worked on now.
iii) In-ship applications (e.g. tank and bilge clean up to minimize overboard discharge) some work has already been done at DREP on this one.

iv) The development of a matching system or systems involving containment, pickup and disposal. Much could and should be done in this area. For example, harbours could be partitioned off through the use of bubble curtains and then a sweep using either a floating boom or a travelling (towed) bubble curtain could be used to move and guide contained spills with pickup by “Slick Lieter” to follow.

Acknowledgement

Assistance has been freely given by many people in the course of the events described above and this help is gratefully acknowledged. There is one person, however, to whom special thanks are extended. He is Mr. Simon P. Nelson of DREP. Without his impressive knowledge of applied mechanics this venture would have been much more difficult.
PART II

REPORT ON STEAM CLEANING

REPORT ON STEAM CLEANING OPERATIONS

FOR PROJECT OIL TASK FORCE

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Steam cleaning operations carried out for Project Oil under direction of Project Oil Task Force by Towne Building Services, Truro, N.S.

Nature of Problem -

A method was needed to remove accumulated bunker oil which had floated ashore from the wreck of the tanker "Arrow" and coated docks and jetties used by fishermen and the general public with up to ½ an inch of tough, weathered Bunker "C" oil.

August 1970
CRITERIA FOR CLEANING METHOD

1. NO DETERGENTS OR SOLVENTS
   - No cleaning methods that increased pollution would be tolerated. The great
     quantities of detergents or solvents that could have been used would undoubtedly
     have had a worse effect on marine life than the oil itself, which was really more of
     a nuisance to man than a menace to sea life.

2. HARDY, RELIABLE EQUIPMENT FOR OUTDOOR USE
   - Because of the wide range of weather conditions, from bright, warm sun to
     pouring rain, high winds to fog, & the necessity to get the job done fairly quickly
     -- the cleaning method had to be such that it could operate in almost any weather
     conditions. Spare parts would be a problem too so the need for such had to be
     eliminated as much as possible.

3. APPLICATION BY UNSKILLED LABOR
   - It was hoped a method could be found which would not require special training
     and which could be applied by relatively unskilled labor.

4. EASE OF LOGISTICAL SUPPORT
   - Cleaning materials had to be readily available and easily supported along the
     entire route of the cleaning operation.

5. PORTABILITY
   - A further criteria was that the method be portable on water aboard shallow draft
     vessels, this being the most logical way to approach the docks and jetties.

STEAM CLEANING MEET THE CRITERIA

1. No detergents or solvents -- Steam's effectiveness resulted from both high heat and
   high pressure. Heat melted the oil and pressure sheared the softened oil away. Steam
   was generated from fresh water without even a spoonful of detergent being used in
   the whole operation.

2. Hardy, reliable equipment for outdoor use -- Steam generation equipment operated
   in almost all weather conditions encountered during the operation. The equipment
   itself was very reliable and very few replacement parts were needed.

3. Application by unskilled labor -- Only one skilled maintenance man was required to
   oversee the operation of the steam generating equipment. The steam gun operators
   being drawn from a variety of non-relevant occupations.

4. Ease of logistical support -- Logistical support for the steam generating equipment
   consisted of supplying fresh water, stove oil, and gasoline, all of which were readily
   available all around Chedabucto Bay.

5. Portability -- Steam generating equipment was light in weight and compact enough
   to be carried on small craft.

SETUP OF A WORKING SYSTEM

An original 50 day or 740 hour operating test was begun starting with 2 model 750 Hy-
Pressure Steam Jenny's mounted on the rear deck of a 38 Cape Island type boat. The
equipment loaded aboard consisted of the 2 steam generators, a portable 2500 watt

electrical plant, a 100 gal. storage tank for stove oil fuel and 5 - 200 gal. storage tanks for
fresh water. Fully loaded our equipment weighed approximately 7 tons.

We began work on the Fisheries Experimental Wharf at West Arichat. This wharf was
badly fouled on both sides and on top and was difficult to clean. In addition the small
harbour created by the wharf was very shallow and at low tide 80% of the wharf was
inaccessible due to lack of water to float our craft. During the first days spent there our
rudder was damaged while maneuvering in shallow water. The difficulties experienced
indicated that the Cape Island boat's draft would be presenting problems often since
many of the jetties to be cleaned were in shallow water.

A specially constructed catamaran was available at the site which was ideally suited to
our needs. She had ample deck area (14' x 26') and good flotation. Our equipment was
loaded aboard. Mobility for the 'Cat' was provided by an L.C.M. which not only towed
the 'Cat' from job site to job site but which also supplied us with fresh water. An L.C.M.
has a carrying capacity in her side tanks of 7 tons of fresh water. The L.C.M. pumped
water into her own tanks from public water sources; fish processing plant docks, and
even fresh water streams emptying into the perimeter of Chedabucto Bay. Fresh water
was then re-pumped into the tanks aboard the 'Cat' as required.

The original tips supplied with the steam guns were round with about 5/8" I.D. The
force of the steam was too concentrated and not practical for our project. New tips were
ordered which spread the steam force across a 4", long opening only 3/32" wide. These
tips were flatter and much more efficient, operating much like a mechanical scraper.
More equipment was needed also to speed the pace of the clean-up. Two more steam

generators were loaded aboard along with another set of fresh water tanks and a fuel
storage tank.

EFFICIENCY RATE AND CONTROLLING FACTORS

Under ideal conditions, with a fully exposed surface at low tide, a flat vertical surface
to be cleaned, with a more or less uniform coating of oil -- a single steam gun working
with 125 to 150 pounds of steam pressure can easily clean 1 square foot per min.
Therefore 4 guns working under the same conditions could clean 4 Sq. Ft./min. or 240
Sq. Ft./hr. These cleaning rates apply without any detergents or solvents being added.

Controlling Factors

1. Bad Weather - Pouring rain reduced the actual efficiency of the steam by cooling the
   work surface and by actually cooling the boiler tubes. (Heavy rain could penetrate
   the superheated exhaust and fall directly on the steam coils) During heavy down-
   pours steam pressure became very erratic, while ordinarily during steady rain we kept
   up full operation.

2. Tide effects. - The changing water levels from the tide had far more effect on our
   operation than was anticipated. It was neither low nor high for very long but was
   nearly always in the process of either exposing the surface to be cleaned or covering
   it up again. It was impossible to steam clean below the surface of the water, however
   the surface to be cleaned extended from above the high-tide mark to the extreme low
   tide mark. This meant that any areas cleaned during a rising of falling tide had to be
   cleaned with a final sweep at low tide to finish parts that had been covered previously.
   Much time was spent in second sweep cleaning at different time/tide levels.

3. Irregular work surfaces - wharves to be cleaned were constructed from vertical
   creosoted timbers, horizontal timbers, bolted timbers, planks, rough tree poles, etc.,
   some had solid walls, some were concrete capped, some had timber tops, some were
   open inside and some were filled with stone, some were lightly oiled and some
   heavily oiled, some were smooth, new wood and some were 20 year old rotten trees

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FULLY EQUIPPED "CAT" LAYOUT

1. Fuel storage tanks for stove oil.
2. Gas engine driven steam generators.
3. Electrically driven steam generators.
4. Portable 2500 watt electric plant.
5. Steam guns with wide tips.
6. Fresh water storage tanks, 200 gal. each.
7. Wheel house for "Cat" used for storing gasoline, motor oil, spare parts, tools.

and some of the breakwaters and retaining walls were constructed of large stones which had pools of oil between them.

4. Occasional mechanical difficulties - The gas-driven electrical generator was sometimes hard to start in the mornings due to continual dampness and the exposed nature of our craft. The burner tips on the steam had to be disassembled periodically for cleaning and adjusting. Water intake valves were damaged occasionally by small stones probably picked up from the variety of our water sources. The steam hoses were very durable but were 125 ft. long for each steam generator, and from time to time one or the other would be snagged or stretched causing a blow-out.

5. Travelling time - With her full load the 'Cat' had to be moved fairly carefully from jetty to jetty and real care had to be taken when long moves were necessary due to her low freeboard. Fog also hampered our small fleet on a number of occasions. However, travel was a must and about 20% of our time was spent in moving about.

CONTROL AND RECOVERY OF REMOVED OIL.

As removed from the docks by steam cleaning the oil was highly fluid and thinned to just a little more than iridescence. In this condition it could not be recovered by the skimmer-liners nor could it be scooped or netted. However, when it arrived on shore it could re-gather into heavy oil again. Therefore special control and recovery techniques had to be devised. This problem had been anticipated by the Project Oil Task Force and when our cleaning operation began we were instructed to use a practical and very efficient control and recovery procedure.

As the oil was removed from the docks it would fall to the water and fan out in thin slicks. A workman was positioned above the steamers on the dock and was assigned to spread peat moss on the floating oil. Peat moss has an affinity for oil and would soon absorb the oil. Other workmen were assigned the task of scooping up the oil-soaked peat moss in dip nets. It was then transported to dump sites in 45 gal. barrels.

As an extra precaution a boom net was positioned around the entire area where steam cleaning operations were being conducted in order to contain any oil or peat moss which was not immediately recovered.

STEAM CLEANING FLEET VESSELS

1. The Catamaran - as described.
2. An L.C.M. - providing mobility, supplying fresh water and carrying supplies of peat moss.
3. An S.P. Barge - used as a work platform from which to recover oily peat moss from the water.
4. The "Strait Queen" - a Cape Island boat and her crew used to handle the boom and also as dip net handlers.